MECHELECIV

SCHOOL OF ENGINEERING AND APPLIED SCIENCE

Westinghouse needs engineers who understand this generation
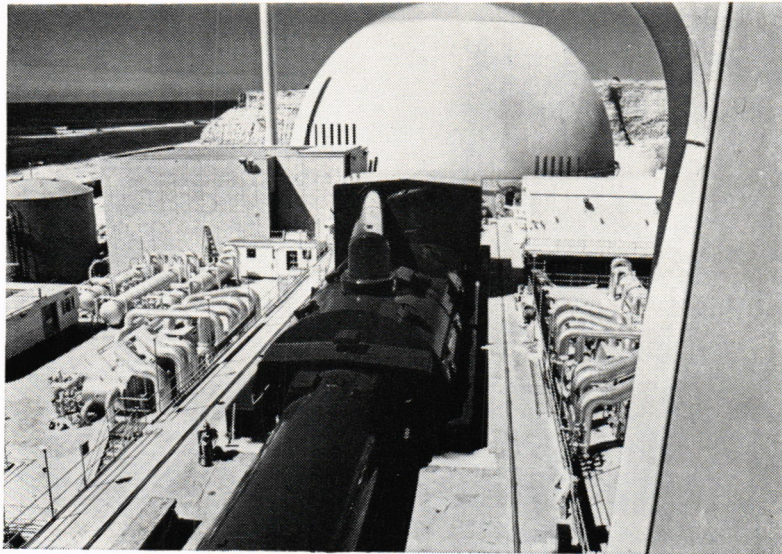
or this generation.

In the next ten years, demand for electricity will double. What's Westinghouse doing about it? Plenty. We're number one in commercial nuclear power. We're working on an advanced breeder reactor. We're spending $450 million to boost our production capacity.

Okay, that's Westinghouse, the electric company. What about Westinghouse, the schoolteacher? In its first two years, Westinghouse Learning Corporation had over 60 government and private contracts, including training for the Peace Corps, Job Corps, and private industry.

Which doesn't even start to describe Westinghouse. We're also in computers, transportation, medical science, air pollution, oceanography, and more. Is that any way to run an electric company?

We think so. If you think so, talk with our campus recruiter, or write Luke Noggle, Westinghouse Education Center, Pittsburgh, Pa. 15221. An equal opportunity employer.

You can be sure...if it's **Westinghouse** Ⓦ

common-base equivalent circuit
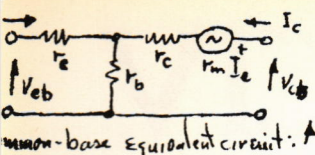
$$V_{eb} = z_{ib} I_e + z_{rb} I_c$$
$$V_{cb} = z_{fb} I_e + z_{ob} I_c$$

$$r_{ib} - r_{fb} = r_e$$
$$r_{fb} = r_b$$
$$r_{ob} - r_{rb} = r_c$$
$$r_{rb} - r_{rb} = r_m$$

short-circuit current gain α | $V_{eb}=0$
$$r_b = \frac{h_{rb}}{h_{ob}} \qquad \alpha = -h_{fb}$$
$$r_e = h_{ib} - \frac{h_{rb}(1+h_{fb})}{h_{ob}} \qquad r_c = \frac{1-h_{rb}}{h_{ob}}$$

$$\left|\frac{I_c}{I_{scl}}\right| = \alpha = \frac{r_b+r_m}{r_c+r_b} = \frac{r_{fb}}{r_{ob}}$$

$$R_{ib} = r_e + r_b - \frac{r_b(r_b+r_m)}{r_b+r_c+R_L}$$

current gain $A_{ib} = \frac{I_c}{I_e} = \frac{-r_b+r_m}{r_b+r_c+R_L}$ $R_{ob} = r_b+r_c - \frac{r_b(r_b+r_m)}{r_e+r_b+R_s}$ [$E_s=0$]

open-circuit impedance parameters

$$V_1 = z_i I_1 + z_r I_2$$
$$V_2 = z_f I_1 + z_o I_2$$

$$z_i = \frac{V_1}{I_1}\Big|_{I_2=0} \qquad z_f = \frac{V_2}{I_1}\Big|_{I_2=0}$$
$$z_r = \frac{V_1}{I_2}\Big|_{I_1=0} \qquad z_o = \frac{V_2}{I_2}\Big|_{I_1=0}$$

Network

voltage gain $A_{rb} = \frac{V_{cb}}{E_s}$
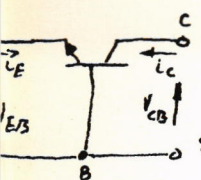
short-circuit admittance parameters

$$I_1 = y_i V_1 + y_r V_2$$
$$I_2 = y_f V_1 + y_o V_2$$

$$y_i = \frac{I_1}{V_1}\Big|_{V_2=0} \qquad y_f = \frac{I_2}{V_1}\Big|_{V_2=0}$$
$$y_r = \frac{I_1}{V_2}\Big|_{V_1=0} \qquad y_o = \frac{I_2}{V_2}\Big|_{V_1=0}$$

$$h_i = z_i - \frac{z_r z_f}{z_o}$$
$$\begin{bmatrix}V_1\\V_2\end{bmatrix} = \begin{bmatrix}z_i & z_r\\z_f & z_o\end{bmatrix}\begin{bmatrix}I_1\\I_2\end{bmatrix}$$

$$h_r = \frac{z_r}{z_o}$$
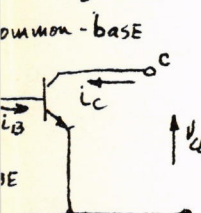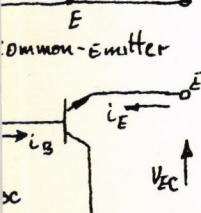
hybrid parameters

$$V_1 = h_i I_1 + h_r V_2$$
$$I_2 = h_f I_1 + h_o V_2$$

$$h_i = \frac{V_1}{I_1}\Big|_{V_2=0} \qquad h_f = \frac{I_2}{I_1}\Big|_{V_2=0}$$
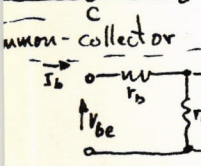$$h_r = \frac{V_1}{V_2}\Big|_{I_1=0} \qquad h_o = \frac{I_2}{V_2}\Big|_{I_1=0}$$

$$h_f = -\frac{z_f}{z_o}$$
$$h_o = \frac{1}{z_o}$$

cathode-follower

driving-point or input impedance $Z_i = \frac{V_1}{I_1} = z_i + z_r\frac{I_2}{I_1} = z_i - \frac{z_r z_f}{z_o+Z_L}$; $\frac{V_2}{I_2}=-Z_L$

grounded grid input resistance

output impedance $Z_o = \frac{V_2}{I_2} = z_f\frac{I_1}{I_2}+z_o = z_o - \frac{z_r z_f}{z_i+Z_s}$; $\frac{V_1}{I_1} = Z_s$

$R_{ie} = r_b + r_e - \frac{r_e(r_e-r_m)}{r_e+r_c(1-a)+R_s}$ output resist.
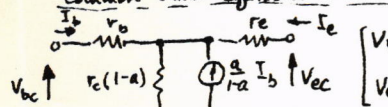
$$V_{be} = (r_b+r_e)I_b + r_e I_c$$
$$V_{ce} = (r_e-r_m)I_b + (r_c-r_m+r_e)I_c$$

$h_{ie} = r_b + \frac{r_e r_c}{r_e+r_c(1-a)}$ $h_{re} = \frac{r_e}{r_e+r_c(1-a)}$

$h_{fe} = \beta = \frac{\alpha}{1-\alpha}$ $h_{oe} = \frac{1}{r_e+r_c(1-a)}$

$R_{oe} = r_e+r_c(1-a) - \frac{r_e(r_e-r_m)}{r_b+r_e+R_s}$

$A_{ie} = \frac{I_c}{I_b} = \frac{r_m-r_e}{r_e+r_c(1-a)+R_L}$ $A_{ve} = \frac{V_{ce}}{E_s}$

Common-emitter equivalent circuit

$R_{ie} = r_b + \frac{r_c(r_e+R_L)}{r_e+r_c(1-a)+R_L}$ current gain $A_{ic} = \frac{I_e}{I_b} = \frac{-r_c}{r_e+r_c(1-a)+R_L} = \frac{-r_c}{r_o+R_L}$

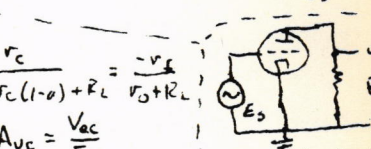$R_{oe} = r_e + \frac{r_c(1-a)(r_b+R_s)}{r_b+r_c+R_s}$ voltage gain $A_{vc} = \frac{V_{ec}}{E_s}$

$$\begin{bmatrix}V_{bc}\\V_{ec}\end{bmatrix} = \begin{bmatrix}r_b+r_c & r_e(1-a)\\r_c & r_e+r_c(1-a)\end{bmatrix}\begin{bmatrix}I_b\\I_e\end{bmatrix}$$

grounded cathode

common-collector equivalent circuit

$$\Delta = h_{ib}h_{ob} - h_{rb}h_{fb}$$
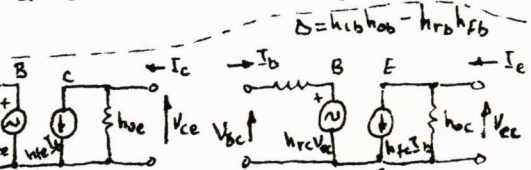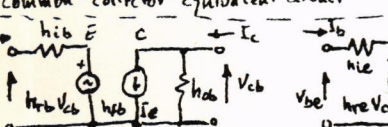
$R_{ib} = \frac{V_{eb}}{I_e} = \frac{R_L\Delta + h_{ib}}{h_{ob}R_L+1}$ $A_{ib} = \frac{I_c}{I_e} = \frac{h_{fb}}{1+h_{ob}R_L}$

$R_{ob} = \frac{V_{cb}}{I_c} = \frac{R_s+h_{ib}}{R_s h_{ob}+\Delta}$ $A_{vb} = \frac{V_{cb}}{V_{eb}} = \frac{-h_{fb}R_L}{R_L\Delta+h_{ib}}$

$$\begin{bmatrix}V_{eb}\\I_c\end{bmatrix} = \begin{bmatrix}h_{ib} & h_{rb}\\h_{fb} & h_{ob}\end{bmatrix}\begin{bmatrix}I_e\\V_{cb}\end{bmatrix}$$

common-base h par. common-emitter h par. common collector h par.

$$\begin{bmatrix}V_{be}\\I_c\end{bmatrix} = \begin{bmatrix}h_{ie} & h_{re}\\h_{fe} & h_{oe}\end{bmatrix}\begin{bmatrix}I_b\\V_{ce}\end{bmatrix}$$

$$\begin{bmatrix}V_{bc}\\I_e\end{bmatrix} = \begin{bmatrix}h_{ic} & h_{rc}\\h_{fc} & h_{oc}\end{bmatrix}\begin{bmatrix}I_b\\V_{ec}\end{bmatrix}$$

$h_{ic} = \frac{h_{ib}}{1+h_{fb}}$ $h_{fc} = \frac{-1}{1+h_{fb}}$

common-emitter

$h_{ie} = \frac{h_{ib}}{1+h_{fb}}$ $h_{fe} = \frac{-h_{fb}}{1+h_{fb}}$

$r_e = \frac{h_{rb}h_{ob}}{1+h_{fb}}$ $h_{oe} = \frac{h_{ob}}{1+h_{fb}}$

$h_{rc} = 1-\frac{h_{rb}h_{ob}}{1+h_{fb}}$ h_{rb} $h_{oc} = \frac{h_{ob}}{1+h_{fb}}$

common collector

$\mu = \frac{g_m}{g_p} = \frac{\partial i_b/\partial e_c}{\partial i_b/\partial e_b} = \frac{-\partial e_b}{\partial e_c}$

amplification factor $\mu = g_m r_p$

voltage gain $|Gain| = \left|\frac{E_o}{E_s}\right|$

instant. grid-cathode voltage $e_c = E_{cc} + e_g = E_{cc} + e_s$

anode voltage cathode voltage $E_b = E_{bb} - I_b R_L$

load volt. rise from cathode $e_o = e_b - E_b$

grid-plate transconductance $g_m = \frac{\partial i_b}{\partial e_c}\Big|_{e_b=k}$ (effectiveness of grid volt in controlling plate current)

vacuum triode
$$\begin{bmatrix}I_g\\I_p\end{bmatrix} = \begin{bmatrix}0 & 0\\y_f & y_o\end{bmatrix}\begin{bmatrix}E_g\\E_o\end{bmatrix}$$

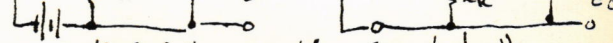instant. total anode current $i_b = I_b + i_p$, if $e_g=0$

instant. total plate volt. $e_b = E_b - i_p R_L$

plate resistance $r_p = \frac{\partial e_b}{\partial i_b}\Big|_{e_c=k}$ (effectiveness of plate volt. in changing current)

$y_i = y_r = 0$ $y_f = g_m$ $y_o = g_p$

grounded-cathode amplifier
$E_o = \frac{-\mu Z_L E_g}{r_p + Z_L}$ voltage gain $A = \frac{E_o}{E_s} = \frac{-\mu Z_L}{r_p+Z_L}$

$I_p = g_m E_g + \frac{E_o}{r_p}$ voltage source

$E_o = -\mu E_g + I_p r_p$

Equiv. for triode two generator Equiv. source current source for triode

grounded grid amplifier
$-E_g - E_s = I_p(r_p+R_1+R_L)$ $A = \frac{E_o}{E_s} = \frac{(\mu+1)Z_L}{r_p+(\mu+1)R_1+Z_L}$
$E_g + E_s = -I_p R_1$

grounded-grid amplifier

equivalent circuit

cathode follower
$E_g = E_s - I_p R_k$ $A = \frac{\mu R_k}{r_p+(\mu+1)R_k}$
$E_g = I_p(r_p+R_k)$

$R_{in} = \frac{h_i + \Delta R_L}{1+h_o R_L}$ $\Delta = h_o h_i - h_r h_f$ $R_{out} = \frac{h_i+R_s}{h_o R_s+\Delta}$

cathode-follower amplifier Equivalent voltage source

MECHELECIV

THE STUDENTS MAGAZINE • VOL. 27 • MAY 1969 • NO. 6

Page

COVER

Planer (Bill Board-Type) Antennas for AN/SPS-32/33, 3-D Fixed Array Computer Radar System on the Bridge of the Aircraft Carrier, USS Enterprise, World's Largest Ship. Courtesy of the Navy Department.

FRONTISPIECE

"We cover over 200 pages in Electronics, and the Prof tells us we can only bring a 8½" x 10" sheet of paper (one side only!) of notes to the final!!!!"

You ask yourself: "Was it all worth it?"

You think back over the years you've invested in that brand new degree. The hard-earned dollars you hoarded from summer jobs—the sacrifice your folks made to help see you through.

You remember the fun you had on campus—and the fun you missed, cramming for exams.

And now comes the moment of truth. *Was it all worthwhile?*

Well, no diploma carries a gilt-edge guarantee. But, *if* you've got it to give. *If* you have the discipline, the drive and desire to extend yourself in a challenging, rewarding, results-oriented environment—

Honeywell can help you make it happen!

You see, advancement comes fast in a growth industry— and *growth* is our business.

Honeywell concentrates in growth fields—electronics, automation, computers, aerospace—dynamic industries where tomorrow is happening *today*.

Honeywell products? Over 13,000 of them! Electronic, mechanical, electromechanical components and systems of all kinds—from computers to climate control systems for homes and buildings, from defense systems to precision switches. Yes, and flight control systems for aircraft and outerspace exploration.

In fact, Honeywell products are so diversified,

the end is nowhere in sight—and the career opportunities are just as unlimited.

So, consider a future at Honeywell. In manufacturing, engineering, sales engineering or marketing; in accounting, production control, data processing and programming; in business administration or economics—the list goes on and on.

And please remember this. Big as Honeywell is—a billion-dollar-a-year corporation, with over 70,000 people in centers from coast to coast, border to border, and beyond—our continued growth hinges on the *individual*. Particularly, on new talent from *your* generation.

We want young people who want to grow— who enjoy probing new areas. Who accept the challenge of new horizons where the sign posts haven't been erected—where the rules haven't been written.

Isn't this what that new diploma is all about? Ask your placement director for the Honeywell *opportunity* brochure.

Talk to one of our recruiters next time he visits your campus. Watch for dates. Or write to
Mr. H. P. Eckstrom,
Corporate Director of
College Relations,
Honeywell,
Minneapolis, Minnesota 55408.

Honeywell
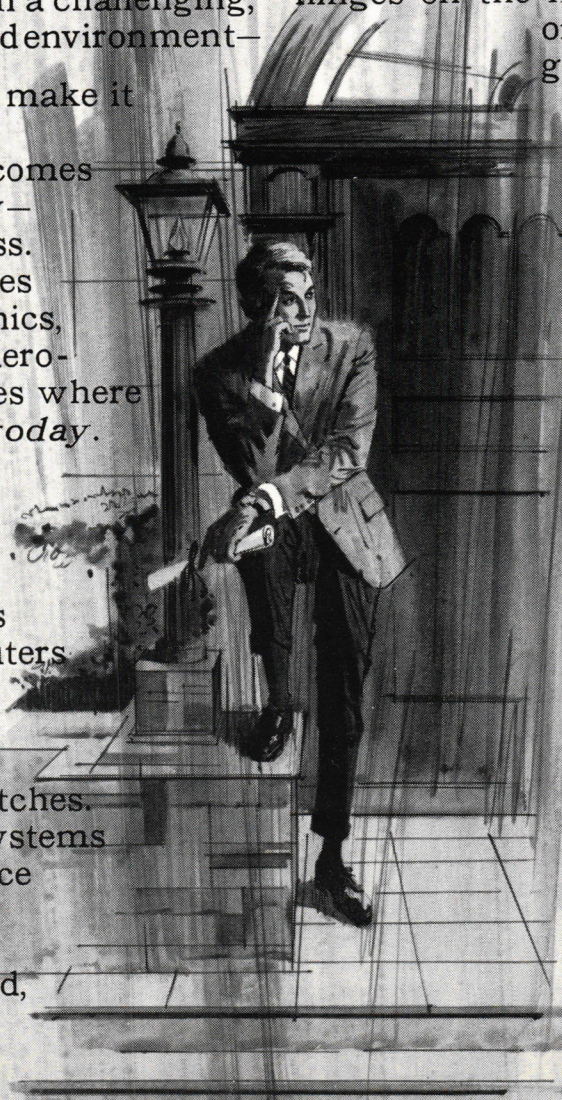
MECHELECIV

With this issue, *Mecheleciv* magazine comes to the end of a year of providing the student body and alumni of the School of Engineering and Applied Science with an informative and what the staff and many people thought was an interesting and improved student periodical.

Many changes have come to the format and operation of *Mecheleciv* magazine this year. Among the more recent, the editorship, with this issue, changes hands. In the past the editors of *Mecheleciv* magazine have come and gone, leaving the magazine pretty much as they found it, and worst of all, without giving regard to whom the new editor would be. Once or twice in the past, the decisive power of the editor was divided up between a Board of Editors. This was done primarily because no person wanted to take on the responsibility alone. This setup, however, proved to be ineffective in turning out a good magazine due to the constant haggling between the editors. Thus, it was finally decided that one person be Editor-in-Chief, having the final way in the content and policy of the magazine.

Until last year, the Editor-in-Chief had more and more difficulty in finding students interested enough to give up some of their time to be on the editorial and business staff of *Mecheleciv*. Two years ago, the lack of student interest became so critical that it almost put an end to the publication of *Mecheleciv*. Fortunately, the desperate faculty advisor to the magazine put together a make-shift staff to put out that year's volume of *Mecheleciv*. Needless to say, the quality of the magazine reflected the lack of interest in it.

After a summer of long discussions between Dean Liebowitz, the *Mecheleciv* staff, and the faculty advisor, great strides have been made this year in putting out a good student magazine. *Mecheleciv* has practically quadrupled its circulation to include all the alumni and off campus students along with the regular student body and faculty. The staff has improved the content and quality of the feature articles and regular departments, re-designed the cover, and most important aroused student interest in putting out the magazine. For the first time, *Mecheleciv* has a system for turning over the editorship while preserving some sort of continuity from year to year.

This system allows the Associate Editor to gradually take over full responsibility of putting out the magazine, finally becoming the Editor-in-Chief of the May issue. In this way he becomes thoroughly familiar with the techniques he will have to use, the deadlines he will have to meet (hopefully), the contacts he will have to make, and the problems he will have to face and overcome in putting out the magazine.

The new *Mecheleciv* staff wishes to thank the outgoing Editor-in-Chief, James B. Bladen, for making *Mecheleciv* a magazine which we can all be proud of. Next year we will have a base upon which we can build, instead of having to put things together from scratch as has been the case in the past. In next year's issues we can look for bigger and better things for *Mecheleciv* magazine.

LETTER TO THE EDITOR

Williamsport, Md.

Gentlemen:

Please note the change of address on the enclosed address label.

Please do not send his mail here any more, particularly your "Students' Magazine" — Mecheleciv. I find your pictures of the young ladies offensive. Do you not know that women need not be undressed, or nearly so, to be attractive? And your "jokes" (and I use the word loosely), aren't even funny. They are filthy and, to me, repulsive.

I am not an alumus(sic) of your great University or any other, for that matter. But if one needs to be educated to appreciate lewdness I'm glad I am uneducated.

There is so much that is fine, beautiful and genuinely humorous that you'd do well to take a good look at what you print.

Respectfully,

Mrs. Lawrence C. Long

Editor's Note: *The staff was disturbed to receive Mrs. Long's letter concerning the April issue.* **Mecheleciv** *magazine is primarily directed toward the interests of the students of the S.E.A.S., and they thought the April issue was great! In fact, the Athletic Department asked us for as many issues as we could give them for use in their recruitment program. We considered this to be a great compliment on the magazine.*

However, we also mail the magazine to nearly 3,000 alumni and distinguished individuals at G.W.U., and thus must listen to their comments also. We also received an irate phone call from an alumnus whose comments fell into line with those of Mrs. Long's. The staff sincerely regrets offending these people in any way. However, only two complaints out of the nearly 3,000 people that read **Mecheleciv** *does not rate eliminating 'Mech Miss' and our joke section (although, in the future, we will try to keep the jokes from getting too filthy). These two complaints do indicate that we should ask others how they feel about these two sections, and ask them to make some suggestions on how we can improve them. In fact, we seek comments on the magazine as a whole.*

Campus News

INSTITUTE FOR MANAGEMENT SCIENCE AND ENGINEERING

A new Institute for Management Science and Engineering has been established in the School of Engineering and Applied Science. Professor H.E. Smith will be Acting Director of this Institute in addition to his duties as Chairman of the Department of Engineering Administration. He will report directly to the Dean of SEAS. Recruitment efforts are being made to attract new faculty, students, and a permanent Director for this Institute.

The purpose of the Institute for Science and Engineering Management is to provide a multi-disciplinary environment for graduate teaching, research and public service. Management science and engineering have been for some time emerging as new and exciting multi-disciplinary endeavors. Traditional disciplines such as mathematics, economics, and statistics have figured prominently in management science and engineering. In addition, newer fields, such as operations research, management science, systems engineering, logistics, and the computer sciences have been developing specialties that amount to varieties or aspects of management engineering. The broad scope of these disciplines attests to the significance of management science and engineering as a vehicle for education and research.

This Institute, which is now the only one of its kind in the Washington area, will provide a visibility for the growing interest, nationally and internationally in management science and engineering; will provide the faculty and students opportunities to engage in unclassified research of multi-disciplinary nature; will strengthen our academic and research programs; will permit SEAS to attract outstanding faculty and students; will be an integral part of this School; will assist SEAS in achieving its objectives in education, research, and public service.

This Institute will function similarly to the other successful one in SEAS, the Institute for the Study of Fatigue and Structural Reliability, under the able direction of Professor A.M. Freudenthal. The intellectual stimulation to result from the additional Institute should be of benefit to our students, faculty, and sponsoring groups.

In order that this Institute may be able to operate immediately, the SEAS part ($150,000) of the NASA Grant EGR-09-010-030 has been transferred to this Institute. Consequently, faculty and students will have an opportunity to engage initially in scholarly studies concerning the implications of the advancement of science and engineering in the present and future space areas. These studies will be coordinated with those being performed by the Program Policy and Planning Group at GWU. Other appropriate areas of research will be undertaken in the future by this Institute to help GWU in achieving its goal "to enrich human life through the preservation, organization, enlargement, and dissemination of knowledge."

ASCE

Saturday, May 3rd, members of ASCE drove to the University of Maryland to attend the 27th annual meeting of the Maryland-District of Columbia Conference of Student Chapters. After being registered, and after a welcoming address, each student chapter president, including GW's Dennis Gallino, gave an annual report of activities. This was followed by the main event of the morning, a presentation by George F. Sowers, Regents Professor of the Georgia Institute of Technology, on Ancient Engineering versus Present Engineering. Though there would seem to be little connection between the two because of the technology difference, parallels were drawn until the two Engineering methodologies seemed identical. Examples were given of identical independent solutions to a certain problem in two widely separated locations in the past.

After the speech, group pictures were taken, followed by a luncheon and presentation of Outstanding Student Awards, one going to our past president, R.J. Keltie.

The afternoon was spent at the Potomac Yards in Alexandria, Va. The tour included the distribution of incoming southbound and northbound freight from one track onto several dozen.

The group was taken into a control tower to watch the automatic and manual switching and braking techniques; and into a data processing center where a record of each car of each train is put on an IBM card for billing and record-keeping. The remainder of the tour consisted of a self guided tour of a switch engine and a question and answer

period. The return to the University of Maryland by bus concluded the conference and the possibility of GW being the next conference host was left open.

TAU BETA PI & SIGMA TAU

The Tau Beta Pi Association announced the Initiation of five undergrads whose scholarship places them in the top eighth of their class in their Jr. year and the top fifth of their class in their Sr. year. Those initiated were: Karen Spindel, Stuart Terl, Curtis Schroeder, Myron Schloss, and Harrison Butturff.

Sigma Tau, the Engineering Honorary Fraternity which recognizes both scholarship and professional attainment, announced the initiation of the following for the spring semester: Professor Theodore Toridis, Professor Nicholas Kyriakopoulus, Bijan Modaressi, James Chandler, Dick Griesel, David Armstrong, and John Clay Davies III.

Each Honorary held elections for the next year. The results are as follows:

TAU BETA PI

President	Bob Keltie
Vice President	Stuart Terl
Secretary	Rodolpho Laporta
Treasurer	Bob Keltie
E C Rep.	Stuart Terl

SIGMA TAU

President	John Clay Davies III
Vice Pres.	David Armstrong
Secretary	Michael Cook
Treasurer	Harrison Butturff
E C Rep	Bob Keltie

AWARDS CEREMONY

On Friday, May 16, the Engineers held their annual Awards Ceremony. A cocktail hour started at 4:00 p.m.

with the awards ceremony following. The first award given was the Tau Beta Pi Award to Mr. Paul M. Haldeman, Jr. for being the most outstanding sophomore. The Sigma Tau Prize went to Mr. Jerrold Bonn for having the highest QPI for a freshman. The following people were awarded keys for serving on the Engineers' Council for at least two semesters: Myron Schloss, Joel Marenburg, Louis Kouts, Chris Kouts, Lenny Sirota, Bob Keltie, Bob Grant, Mike Rohrer, Gurminder Bedi, James B. Bladen, and John Clay Davies III. MECHELECIV Keys were then awarded to the following people for outstanding service: Mark Litchfield, Sid Harmon, Ken Dampier, Dave Armstrong, Bob Grant, Tom Packard, James B. Bladen, and John Clay Davies III. The Deacon Ames Activities Award given by Theta Tau to Mr. Robert J. Keltie, the senior with the mostest. Throughout the evening, John Clay Davies III served as MC, with J. Marshall Azreal as guest speaker.
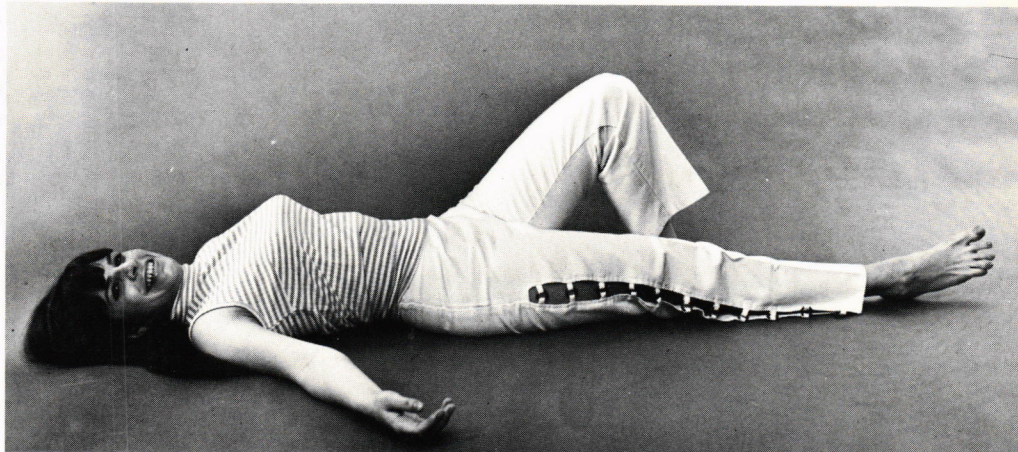
ENGINEERS' WEEK

A new feature I hope to incorporate into the 1970 Engineers' Week Open House, will be a Students' Projects Exhibit. Displays will have to demonstrate engineering in practice and should trace out the project through its development, preferably with photographs or prototype models as well as in written form. Of course, the finished, working model should be on display.
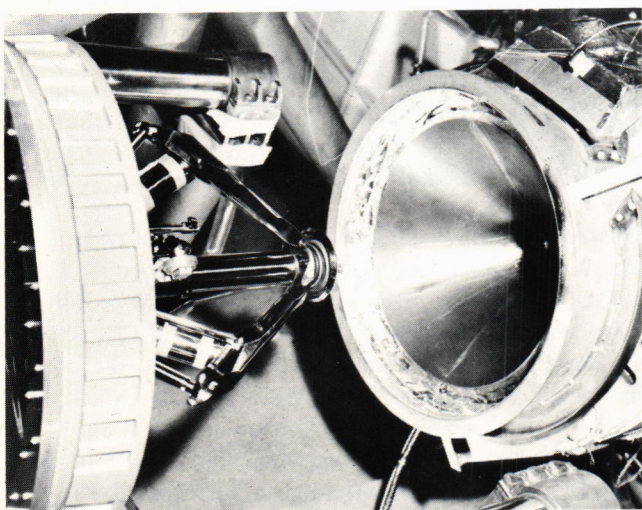
I hope many of you will take advantage of the summer vacation to begin projects or to prepare old projects for this event and help make it possible. Engineers' Week Open House will be conducted during the last week in February of 1970.

—J. Marshall Azrael, Chairman
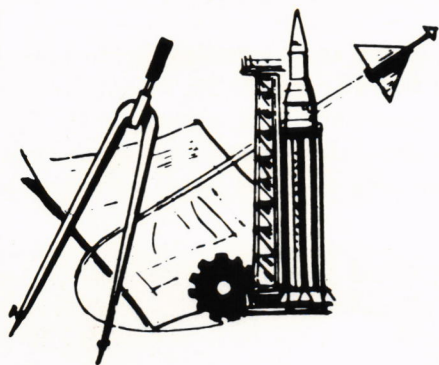
Edited by Gregory D. Smith, E.E., '72

Tech News

Apollo Docking Test Device consists of probe and drogue mounted on docking rings. Hydraulic actuators controlled by an EAI 8900 hybrid computer drive the probe along the X axis, and the drogue along the Y and Z axes.

EAI COMPUTER AIDED SUCCESS OF APOLLO DOCKING OPERATIONS

WEST LONG BRANCH, N.J.—Installed at the Manned Space Center, Houston, Texas, an EAI 8900 Hybrid Computing System was used in the development and evaluation of equipment, systems and procedures under simulated mission conditions. The successful docking of the command and service module and the lunar module during the recent Apollo 9 mission is an excellent example of the value of this kind of simulation. More than 750 dockings were simulated at the Manned Spacecraft Center, Houston, Texas, before the mission.

Purpose of the docking simulation was to insure the structural integrity of the docking mechanism, prove its operation, and determine the envelope of flight parameters,

such as relative speed between vehicles and angle of attack, within which a successful docking maneuver can be accomplished.

These simulations have been carried out on a special, hydraulically-actuated test device. The Apollo Docking Test Device (ADTD) has six degrees of freedom to simulate the relative motion between the docking probe, and the drogue. An 8900 Hybrid Computing System mathematically simulates the motion of the two vehicles being docked and controls the movements of the ADTD. The simulations cover the period from initial contact between the probe and drogue through engagement of the "capture latch," which loosely, but securely, connects the vehicles to the "ring latch" for the final docked position or until the maneuver fails because some maximum condition for docking has been exceeded.

The computer system is an EAI 8900, consisting of a digital and two analog computers. The digital section is programmed to provide initial conditions (positions, angle of attack and relative velocities) of contact. Load cells measure forces encountered by the docking mechanism. Using this information, the analog computers calculate moments and resulting relative rates of motion of the two simulated vehicles. The digital computer converts these values into the relative velocity and position information needed to continuously control the operation of the ADTDs hydraulic actuators.

ALLEGHENY LUDLUM STEEL PRODUCES A NEW NICKEL CHROMIUM ALLOY "ALMAR 362"

Unlimited Class hydroplanes, the biggest, fastest racing power boats in America, skid around the turns at 100 M.P.H., their propellers churning up giant rooster tails of spray 100 feet into the air as they fly down the straight away at over 160 M.P.H. Many are powered by aircraft engines. Most popular are the Rolls Merlin and Allison

"U-8, PARCO'S O-RING MISS," skips along at speeds in excess of 160 M.P.H., churning a rooster tail of spray 100 feet up in the air. "U-8" is testing a new propeller shaft material trade-named "Almar 362," produced by Allegheny Ludlum Steel Corporation.

supercharged fighter plane engines originally developed for the P-51 Mustang.

Such engines develop in the neighborhood of over 2000 h.p. and are geared to drive a hydroplane propeller and shaft at 12,000 r.p.m. This kind of high speed pounding is tailor-made for marine shaft testing.

A strong and ductile nickel-chromium alloy trade named "Almar 362" made its underwater debut as propeller shaft material beneath an "Unlimited Class" racing hydroplane which made the championship circuit in 1968.

Allegheny Ludlum Steel Corporation, producer of the alloy, arranged to have it tested under one of the most demanding marine shaft applications imaginable — racing service on "U-8, Parco's O-Ring Miss," a champion Unlimited Class hydroplane owned and sponsored by Golden State Racing, Inc.

The shaft was 1¾ inches in diameter and 13 feet long. It had a minimum yield strength level of 145,000 psi and a minimum tensile strength of 150,000 psi.

Diameter tolerances were plus or minus .0015; straightness tolerance was .005 inches plus .0015 inches for each foot or fraction thereof in excess of three feet. According to Fred Alter, the hydroplane's famous pilot, the shaft performed with excellence.

According to Allegheny Ludlum's engineers, Almar 362 has the highest tensile strength of all materials offered on the boat shafting market today: the highest torsional strength available for use in boat shafting; and the best cost-to-strength ratio. Although it is the strongest, it is also the lightest. In tests on the alloy, the company reports that Almar 362 has the best wear and abrasion resistance and the highest hardness and highest resistance to galling of any boat shafting material.

$1500 + STUDENT INGENUITY = $60,000 ELECTRONIC MESSAGE BOARD

ALBUQUERQUE, N.M., Mar. 20—A group of engineering students operating on a bargain-basement budget have put together a first-class electronic message board for University of New Mexico sports fans.

The 18-foot-long message board, which hangs above the scoreboard in the 15,000-seat University Arena here, is equipped to flash player names and numbers, words to pep cheers and even emergency messages for fans.

"We figure the materials for the board alone would have cost about $30,000," said Joe F. Colvin II, of Los Angeles, president of Eta Kappa Nu, the electrical engineering honor society whose members designed and assembled it. "But we scrouged around and put the sign together with a total budget of $1500 donated by the Associated Students' Senate."

Helping with the project were such manufacturers as Westinghouse Electric and IBM and local city agencies. The campus Naval ROTC unit and the local Naval Reserve Training Center made available power tools and space for actual construction of the sign. Eberline Instruments Corp. donated the hardware for the sign.
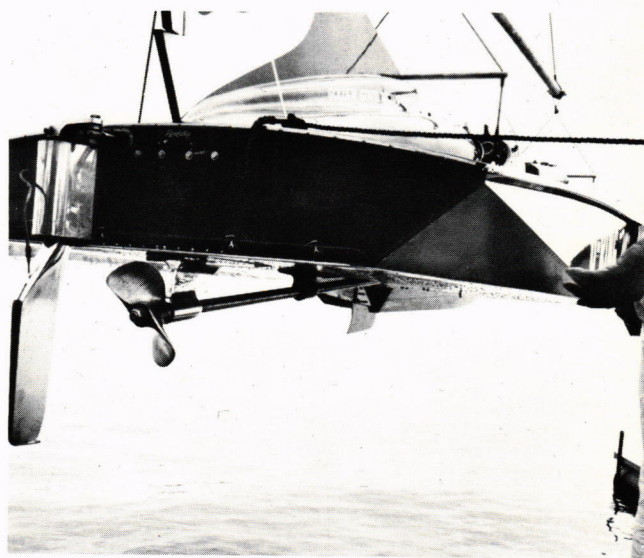
TOUGH AS THEY COME! The propeller shaft on this "Unlimited Class" hydroplane is made of a new, tough shafting material trade-named "Almar 362." The shaft and propeller turn at speeds in excess of 12,000 r.p.m.

The sign has 36 characters formed by arrays made up of a total of 900 red bulbs. The circuits had to be designed so that any letter or numeral could appear in any of the 36 spaces.

Ruben D. Kelly, associate professor of electrical engineering, found a World War II surplus high current power supply and turned it over to the students. The power supply would not meet the design requirements, so the future engineers got hold of a supply of sophisticated electronic components from a kit which Westinghouse had donated to the UNM Electrical Engineering Department.

IBM donated about 400 relays, which were rebuilt by the students and put into the board. Working in shifts, the students drilled and punched 1800 holes in sheet aluminum for the lights and their sockets.

The Associated Students of UNM donated the $1500 to pay for light bulbs, sockets, sheet metal, paint and the 50 miles of wire that went into the board.

J.C. Marous, general manager of the Westinghouse semiconductor division in Youngwood, Pa., which donates kits of electronic components to various engineering schools, said the New Mexico students' accomplishment "takes first prize for uniqueness."

ALBUQUERQUE, N.M., Mar. 20—An electronic message board built by enterprising University of New Mexico electrical engineering students beams a message of encouragement to Lobo basketball players.

INTRODUCING

Mech Miss

Shelisa
Allison
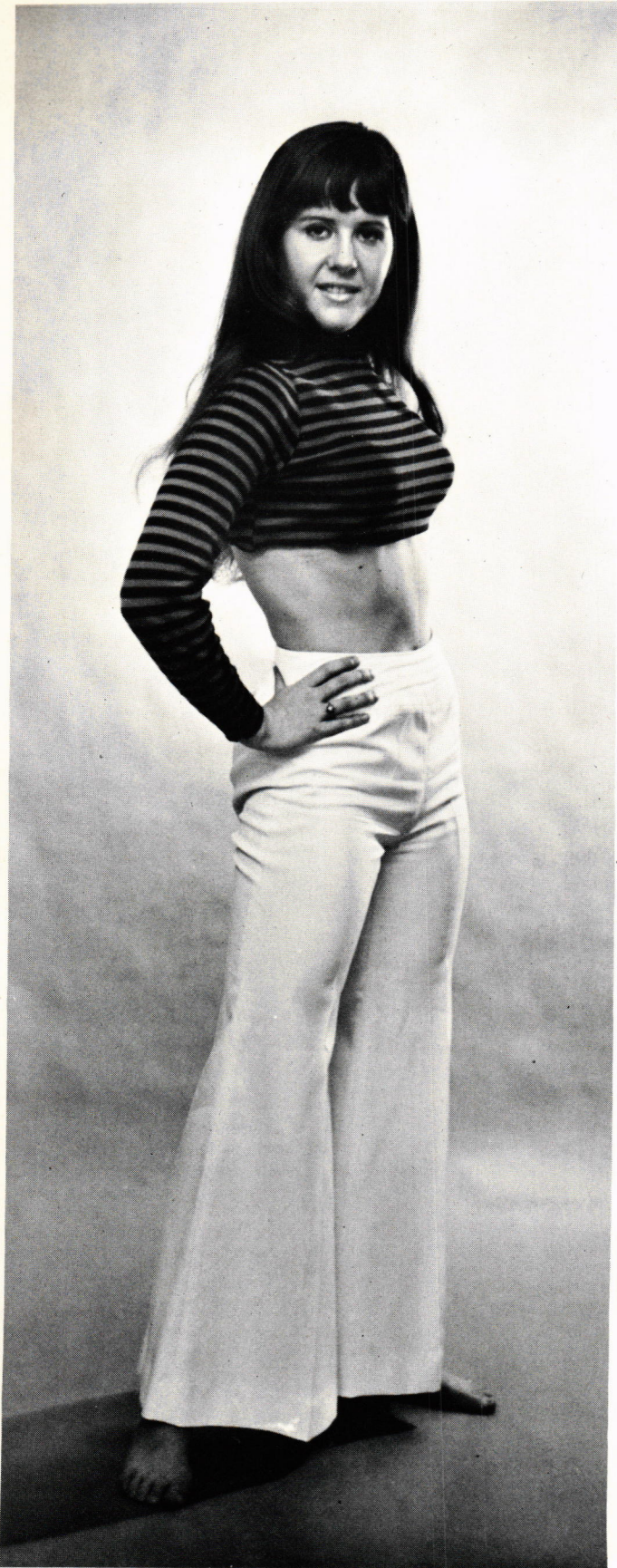
This month's Mech Miss is shapely Shelisa Allison, senior here at G.W.U., majoring in chemistry. She has done undergraduate research on chromium compounds under the direction of Dr. Rowley. Shelisa likes snow skiing and ballet. Shelisa is a member of ZTA and plans to go to Europe next Fall. She says that her younger brother will be coming to GWU next year to major in engineering. We certainly hope she has some sisters as pretty as she is who are interested in engineering for our only girl engineer graduate this year.

MODEL REFERENCE

ADAPTIVE CONTROL SYSTEMS

—A LITERATURE REVIEW—

By Dr. V. Vimolvanich

An **adaptive control system** is a control system that is provided with a mean of monitoring its own performance in relation to a given performance criterion and a mean of modifying its own controlling parameters so as to approach the desired optimality.

Adaptive control systems take many forms. No attempt will be made in this article to review all the different schemes developed in the past. From the up-to-date standpoint, the favorite scheme for adaptive control systems is the model reference scheme. This is true because all of the desired dynamic characteristics of the system can be incorporated into the model and the problem is then resolved into making the system behave like its model.

SYSTEM DESCRIPTION

The model reference adaptive control system can be depicted in block diagram form in the figure below. The adaptive control system consists of the *plant* to be controlled and its associated *adaptive controller*. The *reference model* corresponds to the desired system configuration and can be considered as an implicit characterization of the performance criterion. The reference model and the adaptive control system have the same input. Based on the *performance error*, which is equal to the difference between the model output and the adaptive control system output, the parameters of the adaptive controller are adjusted to minimize the magnitude of the error signal. Thus the adaptive control system strives to maintain its output equal to the desired output generated by the model, despite variation of the plant parameters.

LITERATURE SURVEY

A number of model reference techniques have been suggested as a means for implementing adaptive control systems. For the purpose of orderly presentation, it will be convenient to divide the model reference adaptive techniques into three major categories:

A. *Parameter Adjustment Technique:* In these techniques, the error signal is served as the input to the adjusting mechanism. On the basis of this input, the adjusting mechanism then adjusts the parameters in the adaptive controller so that the error signal is minimized. In order to make the error signal over a period of time equal to zero for non-zero input, it is necessary for the differential equation which describes the overall control system to be identical with that of the reference model. Thus, if the adjusting mechanism operates as described, then the parameters in the adaptive controller will adapt when changes occur in the plant. As a result, the adaptive system response remains close to the model response. The parameter-adjustment approach described above appears to have its origin in the work done by Whitaker, Yarmon, and Kezer (1). However, the concept has been extended and variations added by a number of other investigators. The key difference in each of these extensions is in the detailed operation of the adjusting mechanism. Three general methods are presented below.

Method 1 — Based on the gradient or partial derivative of error function (2,3,4,5). In this method, the adjustable parameters in the adaptive controller are changed continuously at a rate proportional to the negative of the gradient vector of partial derivative of the error function (the error is the same as defined in the figure.)

Method 2 — Based on Liapunov's direct method (6,7,8,9), attempts have been made to use the stability considerations of Liapunov's direct method to derive equations describing the adjusting mechanism. To do this, a positive definite Liapunov function is selected such that the time derivative of the Liapunov function is negative definite. By so doing, the error function is guaranteed to be assymtotically stable, and hence the objective of adaption is achieved.

Method 3 — Based on the convergence criterion of the error signal (10,11,12,13), this approach employs the state-space point of view to obtain analytically the solutions to the differential equations that describe the reference model

Adaptive Control System
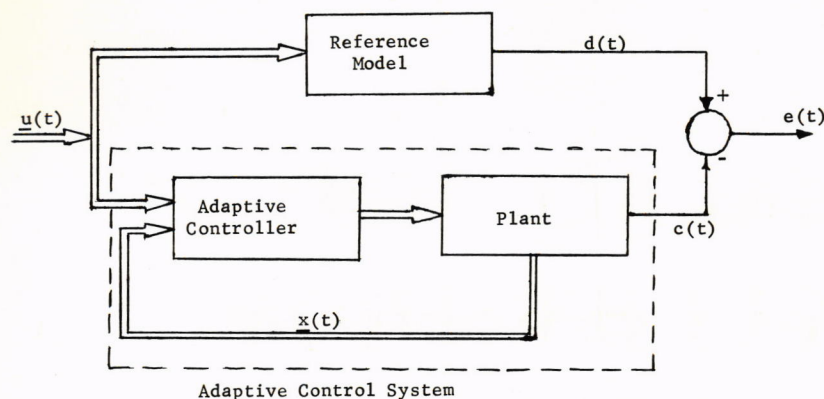
SCHEMATIC DIAGRAM OF MODEL REFERENCE
ADAPTIVE CONTROL SYSTEM

Dr. V. Vimolvanich, known to his students as "Dr. Vim", came to G.W.U. the beginning of this year. Born in Thailand, Dr. Vimolvanich received his B.E. (with honors) from Chulalongkorn University in 1963. He came to America and received his M.S. in 1965 from the University of California, Berkeley; and earned his Ph.D. in 1968 from the University of California, Davis. He is presently an Assistant Professor of Engineering here at G.W.U. Dr. Vimolvanich's areas of interest are in Adaptive Control and Systems Identification. He is also a member of Sigma Xi.

and the adaptive control system. In this way the explicit functional dependence of the performance error on the adaptive parameters can be established. By manipulating the error expression to assume convergence, adaption equations are derived and define the way to minimize the magnitude of the error signal.

B. *Parameter Perturbation Techniques (14,15):* The method described uses the performance-feedback approach. If the performance criterion is assumed to be a function of the adaptive parameters, it may be considered as a hypersurface above the adaptive parameter hyperplane. The objective is to find a setting for the adaptive parameters that extremizes the value of the performance function. Perturbing the adaptive parameters sinusoidally or randomly, one can calculate the partial derivatives of the performance function with respect to the various adaptive parameters by correlation methods. When each parameter is adjusted at a rate directly proportional to the partial derivative or performance function with respect to that parameter, the adaption proceeds toward an extremum approximately in the direction of the gradient on the performance. That is, the adaptive procedure corresponds to a surface search along the path of steepest ascent or descent. A primary objection to this approach is that the perturbation signal appears in the output of the system. It is possible to avoid either the same or a similar form as the adaptive system. In this case, the perturbation signal is applied to the model parameter that corresponds to the system parameter to be controlled.

C. *Identification of Prediction Techniques:* This last approach is quite different when compared to the two already described methods. The main difference is that instead of closed loop control this method is mainly open loop type. There are a few contributions that can be categorized in this section. D.F. Meredith and A.J. Dymock (16) employed a high speed parameter identification approach by using the hill climbing technique to minimize the error be-

tween the response of the system and the response of the model which is governed by the same form of transfer function as the real system. Since the transfer function of the system remains unaltered during a hill climbing process, the parameters of the transfer function of the system can be determined and hence the controller is synthesized. However, the system as such contains no feedback to indicate the degree of success achieved.

J.S. Rice (17) presented an adaptive control technique for minimization of sensitivity effects of a single input, single output plant. Analytically, sensitivity is just a measure of the change in a desired system quantity with respect to a change in some system parameter. By generating the system sensitivity coefficients, it is possible to identify the plant parameters when the output of the plant and the output of a model are given. The system states are next identified and the resultant information of the parameter and state identification process are utilized by a compensator in tandem with the plant input. After each adaption cycle, the identified parameter values are updated and used by the compensator to achieve virtual insensitivity of the plant output to its parameter variations.

There exists an approach employing the philosophy of prediction (18,19). The basic configuration of this type of model reference adaptive control system, described by D. Graupe and G.R. Cassir (18), is that the extrapolation techniques are used for identification and for error prediction. The system employs rectangular adaption pulser of finite duration to minimize a cost functional of predicted square errors as well as weighted squares of the error rate-of-change. P.F. Klubuikin (20) has analyzed an adaptive control system whose unknown parameters can be described by ordinary nonlinear differential equation. The algorithm employs prediction in an accelerated time-scale from a linear model of the plant. The formation of the model and derivation of control signals are constructed by means of a search for the minimum of error-square criterion.

HISTORICAL ACCOUNT OF SNAP-THROUGH PHENOMENA IN THIN SHALLOW SPHERICAL SHELLS

By Ali F. Abu-Taha

Modern engineering structures, particularly those used in space vehicles, aircraft, ships, etc., where it is necessary to reduce the weight to a minimum, are often composed of thin bars, plates and shells. The characteristic property of these structures is their flexibility and their consequent susceptibility to failure due to buckling or instability. A commonly used structural component is the thin spherical cap (used frequently in pressure vessels, or as domes). The resistance of such structures to buckling has been the subject of intense study for the past quarter century.

The purpose of this paper is to present a brief historical account of the theoretical and experimental studies of the snap-through phenomenon of thin, shallow, spherical shells with clamped edges, under uniform pressure. The reader has observed this phenomenon in the behavior of the bottom of an oil can when it is pressed with the thumbs to squirt out the oil. In fact, the phenomenon is frequently referred to as "oil-canning". The geometry of the cap is as shown in figure 1, where it is assumed that $h \ll R$.

As the uniform pressure is applied to the outer surface of the shell, the shell will start to bend. The bending will continue with the load-deflection relationship as shown in the first part of the curves in Figure 2. If the geometrical parameter

$$\lambda = \left[12(1-\nu^2)\right]^{1/4} \frac{a}{(Rh)^{1/2}}$$
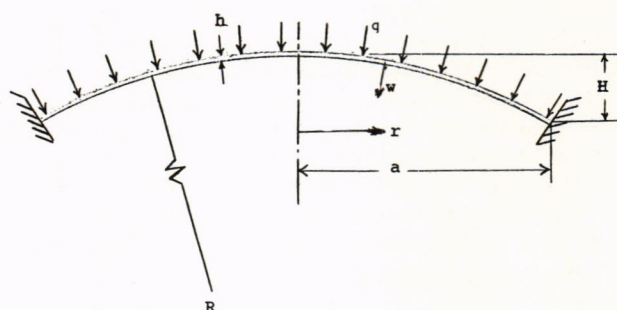
FIGURE 1

is small enough, a continuous increase in pressure causes a continuous increase in deflection. For higher values of λ, it is noticed that when either point a or b shown in Figure 2 is reached, an infinitesimal increase of the pressure will cause a sudden large increase in the deflection of the shell to point c or d respectively, accompanied with a snapping sound familiar to the reader. The primary objective of any analysis of this phenomenon is the prediction of the pressure at which this snap-through or oil-canning occurs.

The problem is inherently a nonlinear one (as can be seen from Fig. 2, the relation between the applied pressure and the resultant deflection is not linear), and the governing equations used in studying the clamped shallow thin shell are:

$$\frac{d}{dx}\left(x\frac{d\theta}{dx}\right) - \frac{\theta}{x} + x\Phi = -2px^2 + \theta\Phi$$

$$\frac{d}{dx}\left(x\frac{d\Phi}{dx}\right) - \frac{\Phi}{x} - x\theta = -\tfrac{1}{2}\theta^2$$

where,

θ represents the rotation of any point in the shell,

Φ represents a stress function,

p represents the applied pressure, and

x represents p/a

and both θ and Φ involve the geometrical parameter,

$$\lambda = \left[12(1-\nu^2)\right]^{\tfrac{1}{4}} \frac{a}{(Rh)^{\tfrac{1}{2}}}$$

FIGURE 2
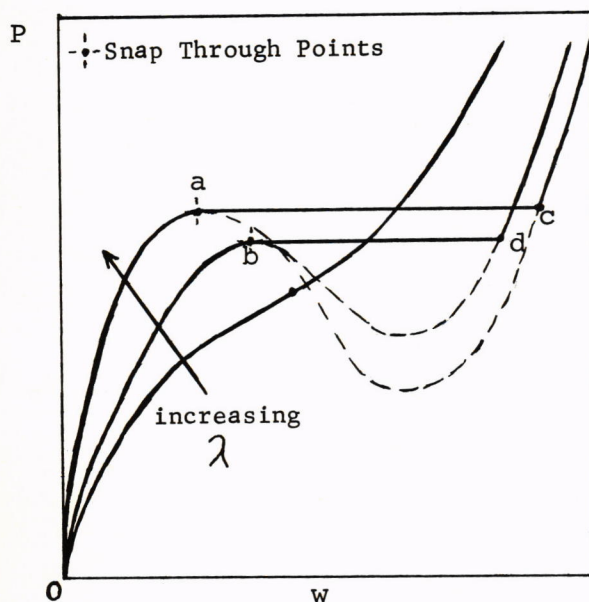**Snap Through Load Deflection Curves**

The pressure P is related to q_o, the buckling pressure from the classical theory of a complete spherical shell of radius R, by the following expression

$$p = \frac{q}{q_o}$$

Many attempts were made in the period 1945-1960 to solve these governing non-linear equations and many techniques were tried, many of them involving numerical solu-

tion with step by step iterations. The results obtained by these efforts were inconsistent and fragmentary as shown in figure 3, where snap-through pressure as a function of λ is plotted. There was also considerable scatter in the experimental results obtained during this period. In 1960-1961, Budiansky (Harvard), Weinitschke (M.I.T.), Thurston (G.E.), and Archer (Case Institute of Technology) working independently of each other, obtained numerical solutions to the governing equations and successfully generated portions Oa or Oc of the load deflection curves in Figure 2. With q_{cr} determined by the lack of convergence of the iteration scheme, all these solutions agreed and are shown in Figure 4. Despite this agreement on theory, this new solution compared less favorably with the existing experimental results than some of the earlier analytical solutions.
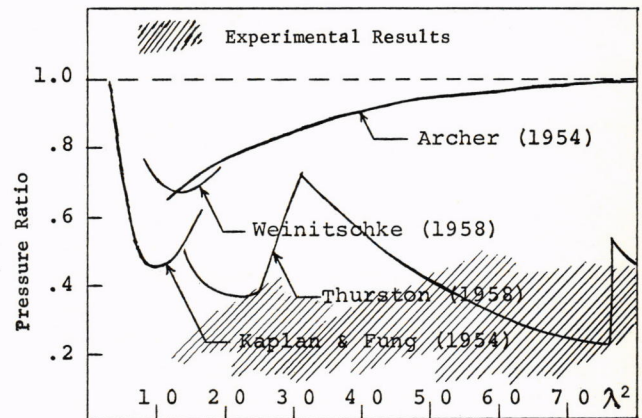

FIGURE 3
Nondimensional Buckling Load as a Function of Shell Geometry

In 1964, Weinitschke obtained a new solution based on more general equations which did not assume that buckling takes place symmetrically but rather, permits it to occur non-symmetrically. His results agreed favorably with experiments as shown in Figure 4. This seemed to be the breakthrough for which engineers were striving. However, at about the same time N.C. Huang, in his Ph.D. dissertation at Harvard, used the same approach as Weinitschke but obtained different results. Huang's solution is also shown in Figure 4. The conflict between these two solutions was soon resolved when Weinitschke discovered a mistake in his computer program. His corrected results agreed with those of Huang, but the gap between experimental results and the analysis was still large.

In 1963, M.A. Krenzke and T.J. Kiernan of the David Taylor Model Basin in Washington, D.C. tested seventeen accurately machined spherical caps under external pressure in order to determine the snap-through pressures. The experimental results obtained by Krenzke and Kiernan are shown in Figure 4, together with their proposed empirical curve which is of the same general shape as the theoretical curves, lying about 10-20% below the theoretical curve. It
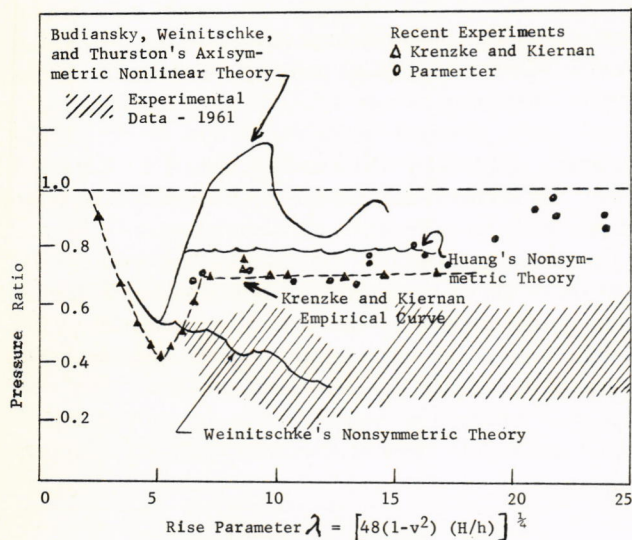
FIGURE 4

Experimental and Theoretical Data for Elastic Buckling of Shallow Spherical Shells with Clamped Edges.

was the first time that there was good agreement between experiment and theory. Krenzke and Kiernan attributed the disagreement that had existed between the theory and earlier experimental data to the presence of initial imperfections in the test specimens which were fabricated from flat plate. The experimental results were supplemented by those obtained by Parmerter of California Institute of Technology in 1963, and also shown in the same Figure.

It appeared as if a complete understanding of the snap-through problem had finally been attained. However, in 1965, Buckner, Johnson, and Moore of University of Wisconsin, and J. Mescall of the U.S. Army Materials Research Agency, obtained the results shown in Figure 5 for load-deflection curve which showed that the simple forms illustrated in Figure 2 do not apply for all values of λ. Notice that several points on the load-deflection curve have horizontal tangents and hence represent points at which snap-through can occur.
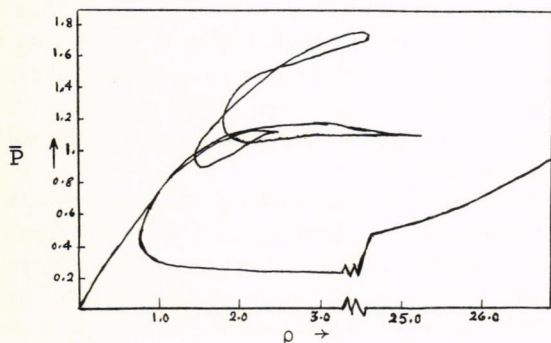

FIGURE 5

Load Deflection Curve $\lambda^2 = 64$ Clamped Edge

Recently B. Hyman of The George Washington University in an attempt to clarify the shape of the load-deflection curve in the neighborhood of the snap through pressure used an approximate analysis developed by W. Nash of University of Florida. He obtained results which agreed with the curves in Figure 2 for small values of λ. For higher values of λ, isolated closed loops were found in addition to the expected curve as shown in Figure 6. A. Kerr of N.Y.U. obtained similar loops in his investigation of snap through of shallow arches, and he proved that they were unstable states of equilibrium.

Most of the research and the development of the snap-through of the shallow spherical shell, and most probably, most of modern engineering undertakings; are carried by universities' professors, students, and associates. This shows the engineering student, especially those who are in their starting years, that the future is full of problems to tackle. Faulty results are sometimes obtained, but they should not discourage him from pursuing the problem at hand. As Man's inquisitive mind and venturesome spirit take him farther and farther from his safe haven and expose him to boundless potential, the engineer must skillfully go on de-
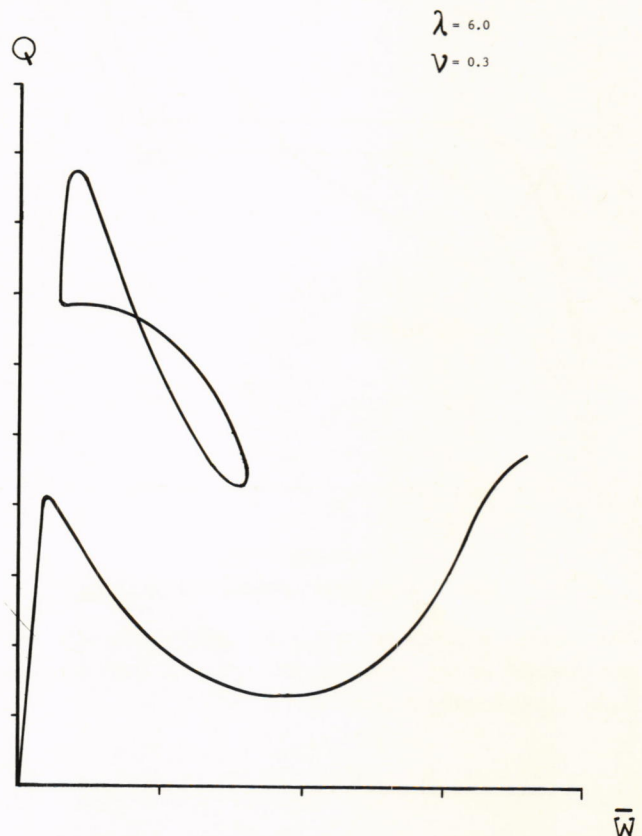

FIGURE 6

Isolated Closed Loops Found for Higher Values of λ in addition to the Expected Curve.

veloping and improving to reach the optimum in any problem or design that faces him, and these are many, of which the shallow spherical shell is one (which may be a part of a space vehicle or an undersea vessel).

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Ali Abu-Taha, a citizen of Jordan, was born in Jaffa, Palestine. He enrolled in the G.W.U. SEAS in 1964 and is presently a senior, majoring in Mechanical Engineering. He is an active member of the Gamma Beta chapter of Theta Tau (the professional engineering fraternity). Ali is presently employed part time by COMSAT. He is interested in doing future research in thin shells or compressible flow. Ali is presently working on compressible flow for his senior lab project.

To All Those Apathetic Students for Their Help:
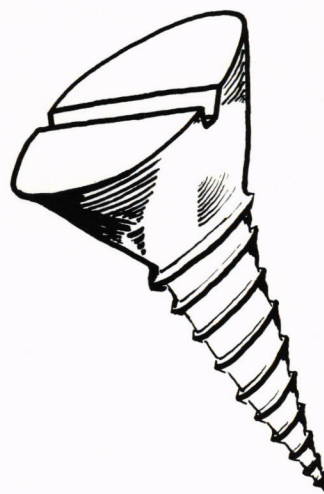
MULTI-MODEL
DIGITAL RADAR CONTROL

By H. Sobel

Currently one of the most dramatic uses of digital computer techniques is the Multi-Mode Radar System. In operation this system performs all of the radar functions which heretofore required separate radar systems. For example, a given radar system might individually operate as an acquisition, search, tracking, weather, guidance, or mapping radar. Some of these radar systems might be ambiguous in target range or target speed while others were designed for either short or long ranges high or low altitude applications; yet others are designed for weather or mapping tasks. Often many radar installations employ several radars to satisfy a particular requirement.

After many years of translating conventional analog techniques into their digital counterparts, it is now possible to realize radar systems which can perform multiple radar functions within the framework of one command system organization. One of the most important digital techniques which has made this possible is the development of the high speed, electronically steerable, phased array antenna.[1] This stationary antenna can be quickly commanded to point a beam to any selected azimuth or elevation within its pointing limits. In addition to this beam pointing agility, it is also possible to shape the beam electronically to form a circular, elliptical or fan-shaped pattern or whatever pattern is required. A digital computer is used to steer this radar beam to a specified azimuth and elevation. This special purpose Beam Steering Computer (BSC) is one of the subsystems in a multi-mode radar. As a matter of fact, most of the digital subsystems in a modern digital radar are special purpose computing devices. Some of these radar subsystems are currently hybrid, in that, they are implemented with both analog and digital techniques. This, however, is a temporary condition and many of the future digital advances will allow designers to replace existing analog techniques with uniform, stable digital implementations. An example of this is the rapid development of digital signal processing techniques which perform filtering and detection processes previously reserved for conventional quartz or LC filters. Consequently, the subsystem which performs these operations

within a multi-mode radar is often referred to as a Digital Signal Processor (DSP) or a Radar Signal Processor (RSP).

Another special purpose processor is one which processes only missile telemetry data. It, like the DSP, employs digital techniques after its input video signals have been converted into a digital form.

All these subsystems are centrally controlled by a general purpose computer whose primary function is to determine radar action sequences, establish target threats, update target files, compute missile-to-target commands and many other executive and operational functions. A simplified diagram of data flow for a digital radar is presented in Figure 1. The waveform generator shown in Fig. 1 is often incorporated as part of the receiver. Its primary function is to supply the transmitter with the pulse waveforms which are appropriate for a particular radar mode. These wave shapes may vary in pulse width, and in the number of periodic or aperiodic pulse trains.

SYSTEM ORGANIZATION

The system organization in Figure 1 does not portray the communication and control uniformity which is possible in a multi-mode radar system. Actually there are several levels of data and command control desirable in a digital radar. These can be summarized as follows:

1. radar data
2. timing control triggers
3. high speed radar data
4. error localization data

A more comprehensive system organization/partioning which illustrates these data and control paths is shown in Figure 2. In this paper, the emphasis will be the radar por-

tion of the multi-mode radar. (The radar portion may be defined as all of the special purpose subsystems other than the general purpose control computer.) In particular, the operational command control aspects of this system will be discussed here.

DATA COMMUNICATION

In order to communicate with each radar sybsystem, it is desirable to establish a standard method for the entire system. This communication is best accomplished by means of the radar data bus. Each subsystem is assigned an address which is used by the Central Processing Unit (CPU) in order to send data to, or from, a particular radar subsystem. Some of the data transmitted to the radar portion of this system might include:

1. operating mode
2. processing constants
3. steering commands
4. missile commands
5. timing data
6. display data
7. transmitter commands
8. diagnostic data

Conversely, the radar portions of this system may send data to the CPU. This data typically includes:

1. processed data returns
   a. radar signals
   b. missile signals
   c. countermeasure data
2. platform data (airborne systems)
3. diagnostic data

It should be noted that some of the radar subsystems operate independently of the system's operating mode. One such unit is the beam steering computer (BSC) which requires only a pointing command that is a function of azimuth, elevation, frequency and beam shape. This computer does not need to know whether the radar system is operating in a single pulse, multiple pulse, tracing, search, or weather mode. However, like all subsystems, it must respond to diagnostic requests in the event of a malfunction or a test.

A command data bus has the advantage of enabling the radar system to be expanded or contracted in order to produce a family of airborne or ground-based multi-mode radar systems. It is assumed that the packaging would be compact in either case.

TIMING CONTROL

A multi-mode radar operates by time sharing of radar actions. These actions are arranged as nearly contiguous as is possible within the operating capabilities of the subsystems. For example, it may be desirable to organize some of the subsystems internally so that they can operate simultaneously upon two radar actions. This may necessitate a dual rather than a single transmitter, receiver, signal processor, or radar control unit.

Radar actions are arranged in an event schedule. The number of events is constrained by a fixed unit of time, called a major action time, during which a predetermined set of radar actions must occur. It should be noted that not all radar actions require the same execution time. A sequence of radar actions, is called a radar schedule; and this schedule is stored within the CPU. The next step is to develop a series of data words which can be transmitted, via the radar data bus, to each respective radar subsystem. The function of these data words is to pre-condition the radar for a particular radar action. The pre-conditioning time is not particularly critical provided that the entire system has been conditioned prior to a scheduled radar action execution time. The execution time is contained in the radar data and is sent to the Radar Control Unit (RCU). This subsystem contains a master clock which is modulo major action time. This means that it counts small units of time such as 50 or 100 nanoseconds until it adds up to a 50 or 100
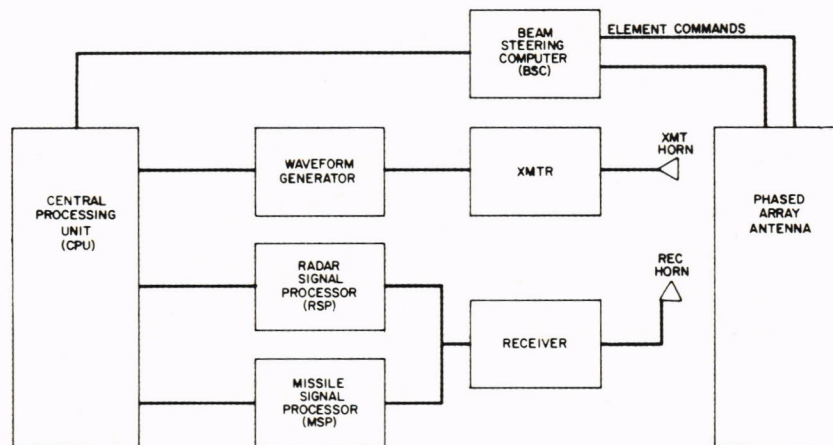

Figure 1. Simplified Digital Radar

millisecond time interval. It then repeats this counting interval periodically. Thus, a sequence of radar actions is scheduled to be executed at prescribed times within this major action time interval. The RCU is functionally a stored trigger generator which issues a series of precise trigger commands to each of the radar subsystems in an appropriate sequence and at the correct time for a particular radar action. These triggers represent the fine timing control for the multi-mode radar and the data words in essence represent course time. When real time exceeds a scheduled radar execution time, the radar action is aborted and the RCU notifies the CPU that a scheduling error has been made. This condition usually cannot occur unless a programming error has been made or system malfunction is present.

REAL TIME DATA

The next level of data transmission is the high-speed real-time data. This information is the result of a local radar process, such as the spectral analysis for a clear operation frequency, which may be locally ascertained and cannot be quickly inserted within the data word queue located in the CPU memory. The radar subsystems normally are in a state of requesting information from this queue except when all systems in the radar have been preconditioned. At this time, the request for data is blocked by one of the subsystems; and the radar is considered to be busy. At some point during the execution of a radar action, some subsystems may be available to accept new radar action data and; consequently, a data request to the CPU could be made. However, only the subsystem which initially blocked the radar channel can release it. In this manner data transmission

adapts to the operational status of the system. When the last scheduled work in the CPU radar queue is transmitted, the queue is refilled and the process is repeated.

The data which is returned to the CPU is a function of the radar action being executed, target status, environmental noise, etc. In some modes data, as a block of words, is sent from the Radar Signal Processor (RSP) to the CPU; in other modes it may originate from the Missile Signal Processor (MSP), receiver or the RCU. The request for the CPU to accept data originates in a given subsystem. When the CPU honors this request, it addresses the selected subsystem and data transmission to the CPU occurs. This data is processed further within the CPU.

DIAGNOSTIC DATA

The last level of data transmission within the radar is the error localization path. Since the entire system performance depends on a series of microsteps or microactions, it is desirable that a gross check procedure be incorporated into a system of this sort. For example, it is mandatory that data be loaded into the Beam Steering Computer (BSC) before it computes antenna element commands. It follows that it is essential that this computation be complete before element commands are jammed into the antenna elements and a transmitter pulse is initiated. Any error in this operational sequence constitutes an operational error. The CPU must be informed of this situation in order to initiate the appropriate corrective and/or diagnostic procedures. Another form of error previously mentioned is the scheduling which results in the detection of transmitter failure. There are literally thousands of possible errors; however, these can initially be detected from a major failure point of
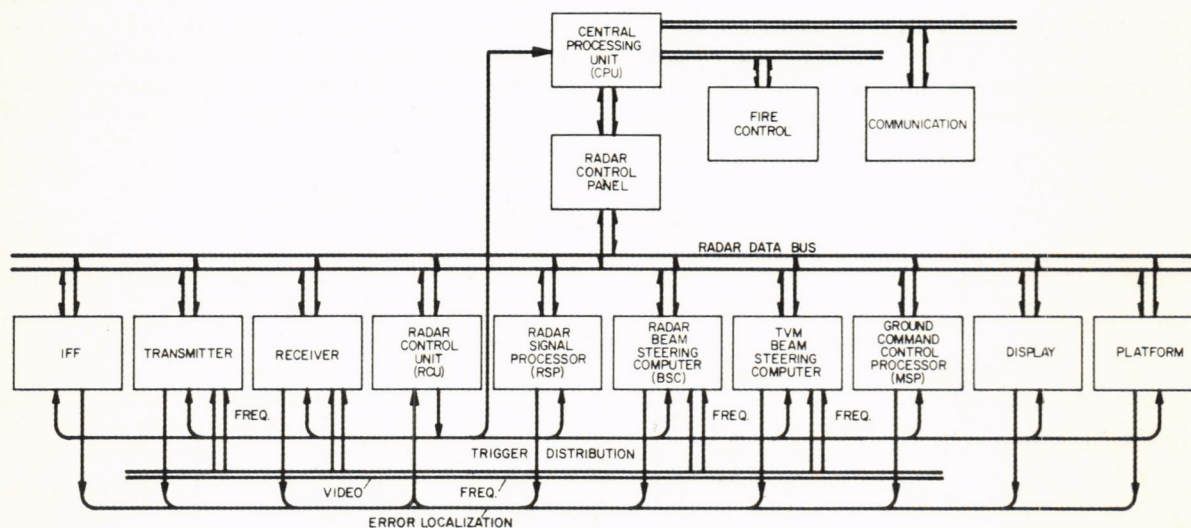
Figure 2. Universal Multi-Mode Radar Organization

view as the first step in error localization. The computer cannot handle so many error signals as individual interrupt requests; consequently, they are combined into one error interrupt request to the CPU. At the same time, information about the particular class of error and its source can be centrally stored in a device such as the RCU. When the error condition is acknowledged; the CPU will request that the RCU transmit its stored error data. After the CPU receives this data, it will ascertain the nature of the error, and its source and initiate a subsystem diagnostic routine if warranted. A sophisticated operational program might in turn activate a system reconfiguration subroutine which would allow the system to continue operating in a reduced performance mode. Since a systems self-diagnosis capability depends so strongly on internal organization, it is essential that this aspect of a system design be incorporated as an initial functional requirement. It cannot be an afterthought if it is to be reasonably effective.

SUMMARY

In this paper some of the operating communication and control paths of a multi-mode radar have been discussed. The organization presented here stratifies the system interfaces into four levels. The two main paths are radar data bus and trigger distribution. This flexible method of communication allows one to postulate a universal multi-mode organization which also provides for individual fault detection as well as diagnostic error localization, a capability which is essential in complex digital systems.

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Tale
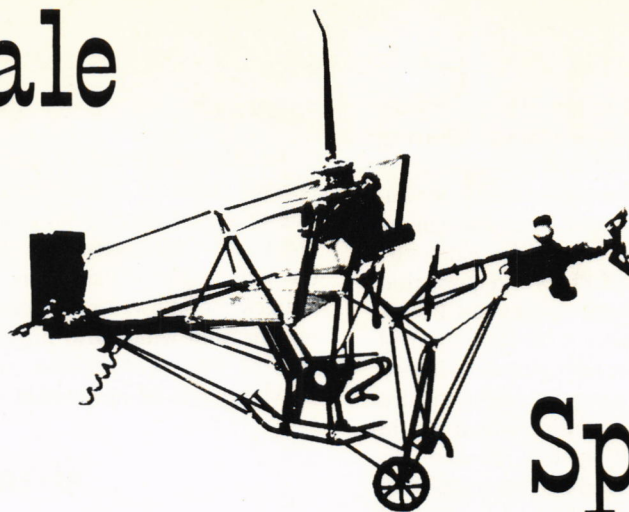
Spin

Once upon a time (1/T) pretty little Polly Nominal was strolling across a field of vectors when she came to the edge of a singularly large matrix.

Now Polly was convergent and her mother had made it an absolute condition that she must never enter such an array without her brackets on. Polly, however, who had changed her variables that morning and was feeling particularly badly behaved, ignored this condition on the grounds that it was insufficient and made her way in amongst the complex elements.

Rows and columns enveloped her on all sides. Tangents approached her surface. She became tensor and tensor. Quite suddenly, three branches of a hyperbola touched her at a single point. She oscillated violently, lost all sense of directrix and went completely divergent. As she reached a turning point she tripped over a square root which was protruding from the erf and plunged headlong down a steep gradient. When she was differentiated once more she found herself, apparently alone, in a non-euclidan space.

She was being watched however. That smooth operator, Curly Pi, was lurking inner product. As his eyes devoured her curvilinear coordinates, a singular expression crossed his face. Was she still convergent, he wondered. He decided to integrate improperly at once.

Hearing a vulgar fraction behind her, Polly turned round and saw Curly Pi approaching with his power series extrapolated. She could see at once, by his degenerate conic and his dessipative terms that he was bent on no good.

"Eureka," she gasped.

"Ho, ho," he said. "What a symmetric little polynomial you are. I can see you're bubbling over with secs."

"O Sir," she protested, "keep away from me. I haven't got my brackets on."

"Calm yourself, my dear," said our suave operator. "Your fears are purely imaginary."

"I, I," she thought, "perhaps he's homogeneous then."

"What order are you?" the brute demanded.

"Seventeen," replied Polly.

Curly leered. "I suppose you've never been operated on yet?" he asked.

"Of course not," Polly cried indignantly. "I'm absolutely convergent."

"Come, come," said Curly. "Let's off to a decimal place I know and I'll take you to the limit."

"Never," gasped Polly.

"Exchlf," he swore, using the vilest oath he knew. His patience was gone. Coshing her over the coefficient with a log until she was powerless, Curly removed her discontinuities. He stared at her significant places and began smoothing her points of inflexion. Poor Polly. All was up. She felt his hand tending to her asymptotic limit. Her convergence would soon be gone forever.

There was no mercy, for Curly was a heavyside operator. He integrated by parts. He integrated by partial fractions. The complex beast even went all the way around and did a contour integration. What an indignity. To be multiply connected on her first integration. Curly went on operating until he was absolutely and completely orthogonal.

When Polly got home that evening, her mother noticed that she had been truncated in several places. But it was too late to differentiate now. As the months went by, Polly increased monotonically. Finally she generated a small but pathological function which left surds all over the place until she was driven to distraction.

The moral of our sad story is this. If you want to keep your expression convergent, never allow them a single degree of freedom.

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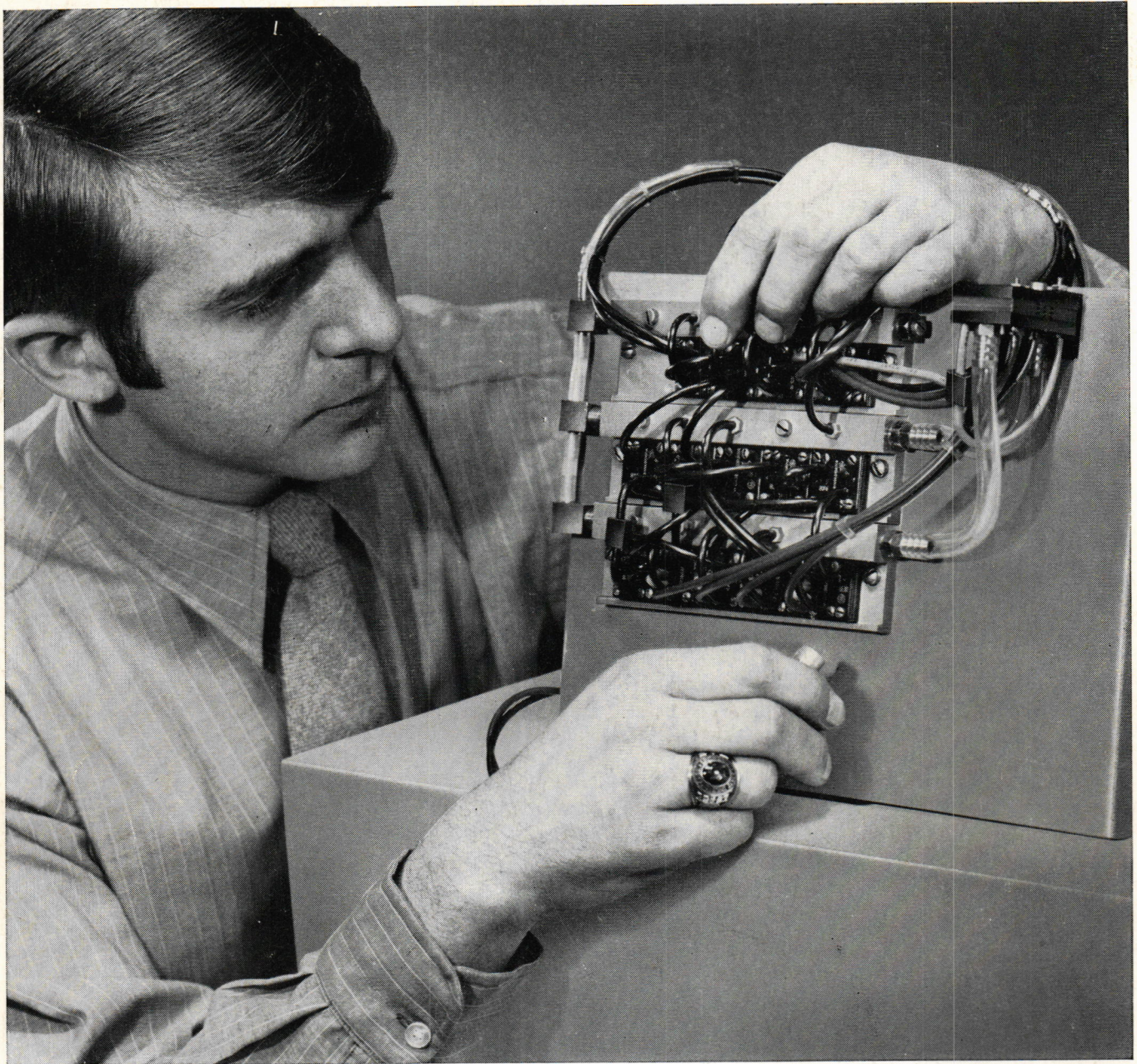
A lot of study, and hard work, never hurt anyone.

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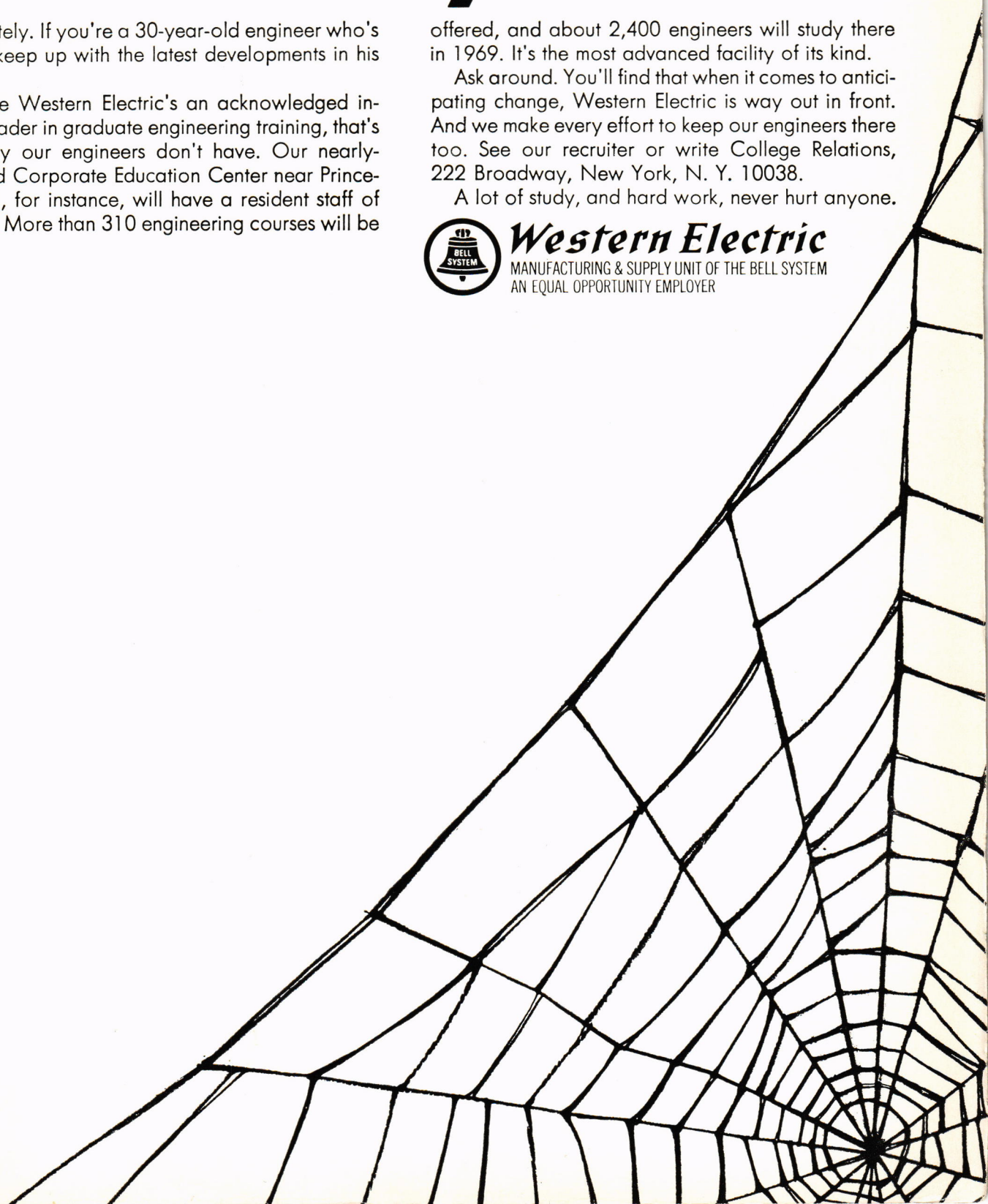
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